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Patent
Attorney's Docket No. 033768-002

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	)	
	)	
Rainer K. Schmid	)	Group Art Unit: 3728
	)	
Application No.: 09/827,933	)	Confirmation No: 6673
	)	
Filed: April 9, 2001	)	Examiner: Mohandesi, Jila M
	)	
For: ENERGY RETURN SOLE FOR FOOTWEAR	)	

DECLARATION UNDER 35 CFR §1.132

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

I, Ron Averill, declare that:

1. I have a Ph.D. in Engineering Mechanics from Virginia Polytechnic Institute and State University (Virginia Tech).

2. I have served on the faculty at Michigan State University in the Departments of Materials Science and Mechanics, and in the Mechanical Engineering Department since 1992. I perform research and teach courses at all levels in the areas of theoretical and computational structural analysis and design.

3. I have reviewed the Z-Spring design of U.S. Patent No. 4,592,153 (Jacinto) and have assessed the structural flexibility of the Z-Spring design by accepted practices of computational modeling to estimate the resistance of the Z-Spring to lateral deflections caused by forces associated with running.

4. The Z-Spring analysis and results are described in detail in the attached report.

5. The Z-Spring design severely limits lateral motion under a direct lateral load due to its geometry. The attached analysis shows that the Z-Spring design exhibits negligible lateral deflection due to a direct lateral load.

6. Modification to the materials, thicknesses, and spring constants of the Z-Spring will not alter this conclusion, as the response of the Z-Spring is governed primarily by its inherent shape.

7. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

by: Ron Averill date: 6/23/03
Ron Averill

Assessment of Lateral Deflection in a Z-Spring

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1. Introduction

The structural flexibility of a Z-Spring heel construction design was studied. The Z-Spring is proposed for use as an energy return mechanism in shoes. In particular, the question of whether the Z-Spring system is capable of accommodating horizontal relative deflection was investigated using accepted practices of computational modeling to estimate the resistance of the Z-Spring to lateral deflections caused by forces associated with running. The lateral deflection of interest is in the 3-direction, as shown in Figure 1.

The finite element method (FEM) was used to analyze the Z-Spring. The FEM is a computational method that is often used to estimate the deflections, strains and stresses in a structure that is subjected to known loads. Even though the FEM is an approximate method, it is considered to be very accurate for problems in which the deflections are moderate and the material behaves in the linear range. Such is the case in the present investigation. The commercial finite element software package ABAQUS was used in the current study.

2. Model Description

For the current computational models, both the spring design and loading conditions were chosen so as to maximize the opportunity for lateral deflection to occur. In other words, an attempt was made to consider a worst case scenario.

The Z-Spring geometry was deduced from the figures in Patent #4592153, dated June 3, 1986. The basic model is shown in Figure 1. Plate section thickness values of 4mm and 3mm were considered (thinner plate sections resulted in very large vertical deflections when the vertical load components were applied). In each case, the width of the spring was assumed to be 75mm; the length of the spring was assumed to be 72mm; and the total height of the spring was assumed to be 24 mm. The lateral deflection behavior under investigation is not highly sensitive to these assumed dimensions. All other springs and cylindrical rubber inserts were ignored, since these would have either no effect on the lateral deflection or in some cases would serve to increase the spring's resistance to lateral deflections.

It is not possible to accurately specify the loading on the Z-Spring during running, since such loading depends strongly upon the bodyweight and biomechanics of the runner as well as the running speed. In the present study, it is assumed that the top plate of the spring is fixed relative

to the foot, and a load is applied at one of the bottom corners of the Z-Spring. This is a worst case scenario. In this case, the *lateral* load on the Z-Spring was *estimated* as follows. Studies have shown that the impact force due to running is approximately 3.0 – 3.5 times the bodyweight of the runner. Since a higher force will yield larger deflections, a conservative magnification factor of 4.0 was chosen. A bodyweight of 150 lbs was assumed. So the total effective impact force considered was 600 lbs, which was assumed to act perpendicular to the ground. It is further known that, at heel strike, the biomechanics of many runners is such that the lower leg and foot are not vertical with respect to the ground. Instead, an angle of approximately 15 degrees – 30 degrees exists between the lower leg and the vertical to the ground, as shown in Figure 2a. So the force on the Z-Spring is not purely normal to the through-thickness axis; there will be both a normal and a lateral component, as shown in Figure 2b. A similar situation may exist at toe-off. The larger the angle of incidence of the force, the larger the lateral component of force on the spring. In the present study, a relatively large angle of 30 degrees was assumed. Therefore, the lateral force on the Z-Spring is estimated to be 600 lbs * sin(30 degrees) = 300 lbs. The direction of loading is shown in Figure 3. The top plate is constrained against all motion (fixed relative to the foot – no sliding). Note that this assumed lateral loading scenario on the Z-Spring is probably more severe than would be experienced in most realistic cases.

3. Results

The predictions of lateral deflection of the Z-Spring are presented in Figures 3 and 5 for the cases of 4mm and 3mm plate thicknesses, respectively. When the plate thickness was 4mm, the maximum lateral deflection was predicted to be slightly less than 0.4 mm. When the plate thickness was 3mm, the maximum lateral deflection was predicted to be slightly less than 0.6 mm. These results show that the Z-Spring exhibits *very* small lateral deflection due to a large direct lateral load. Reducing the plate thickness would increase these lateral deflections slightly, but they would still be very small. Taking into consideration the fact that the loading conditions considered here are probably excessive, it can be concluded that the Z-Spring will exhibit *negligible* lateral deflections under normal loading conditions.

The Z-Spring design concept severely limits this type of lateral motion due to its geometry. The joints are very stiff, and each plate acts like a shear panel that resists the type of lateral deflection under investigation. Making modifications to materials, thicknesses and spring constants will not alter this conclusion, as the response of the Z-Spring is governed primarily by its inherent shape.

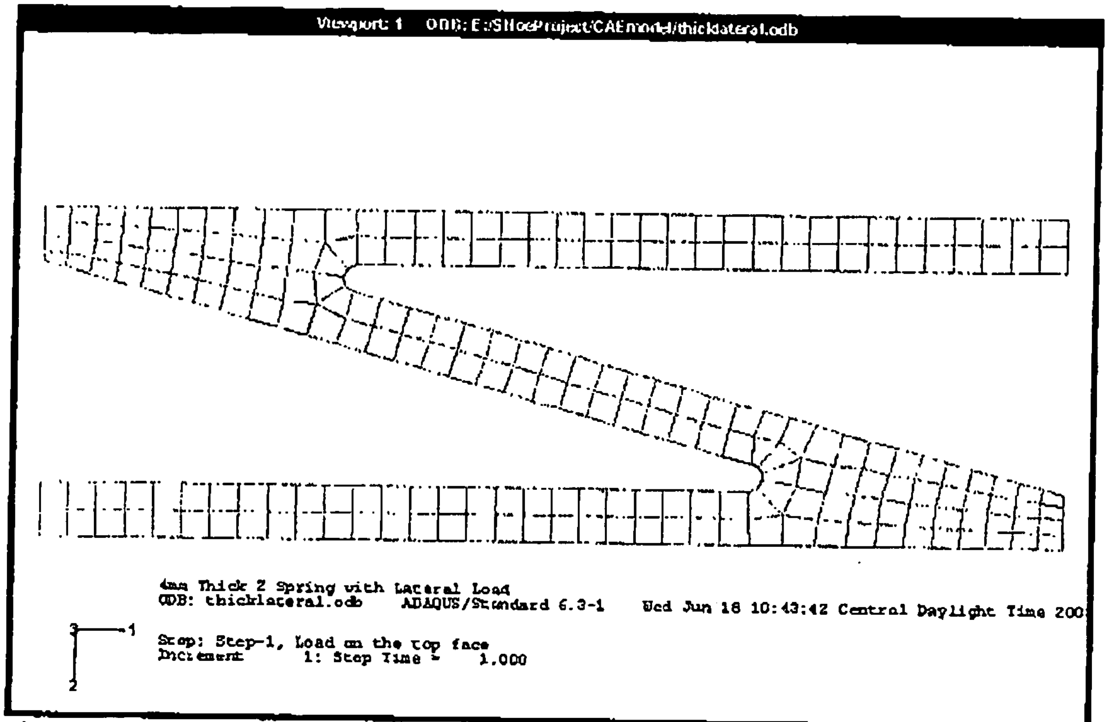

Figure 1. Undeformed spring with plate thickness of 4mm.

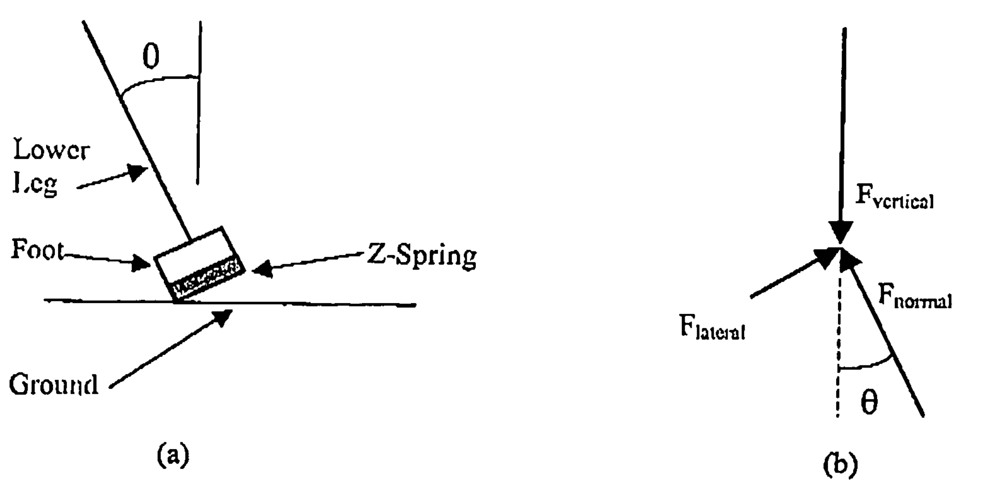

Figure 2. (a) Angle between the lower leg and vertical direction at heel strike, and (b) components of the force on the Z-Spring.

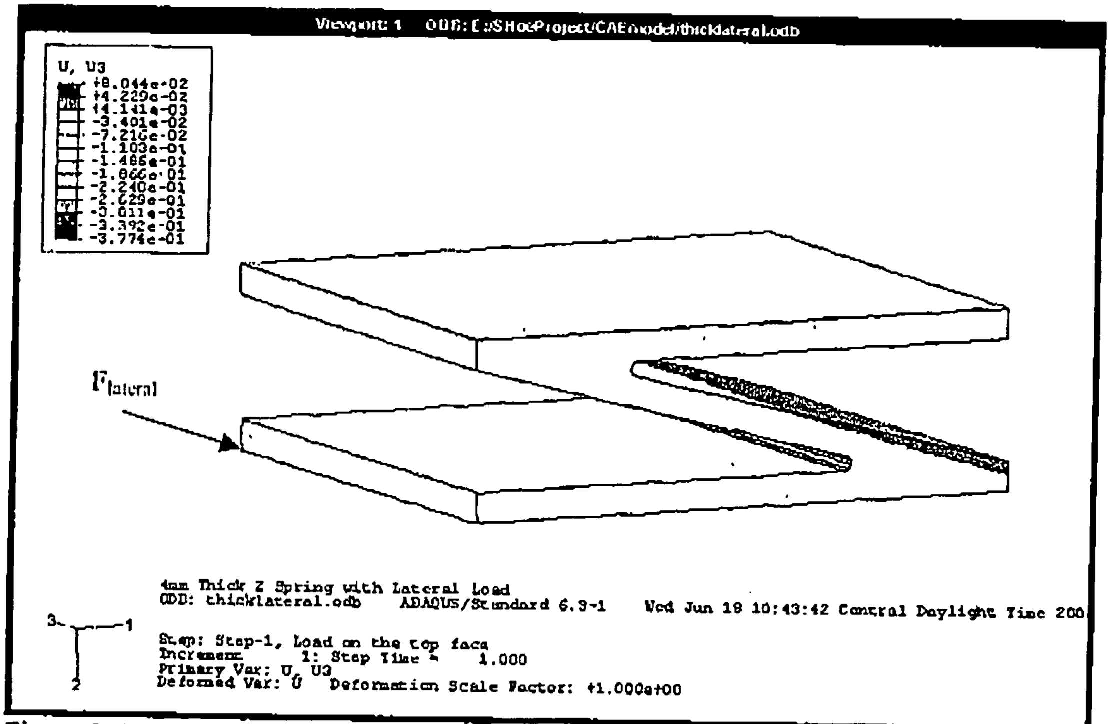

Figure 3. Lateral deflection (mm) of Z-Spring with 4mm thick plates under lateral point load.

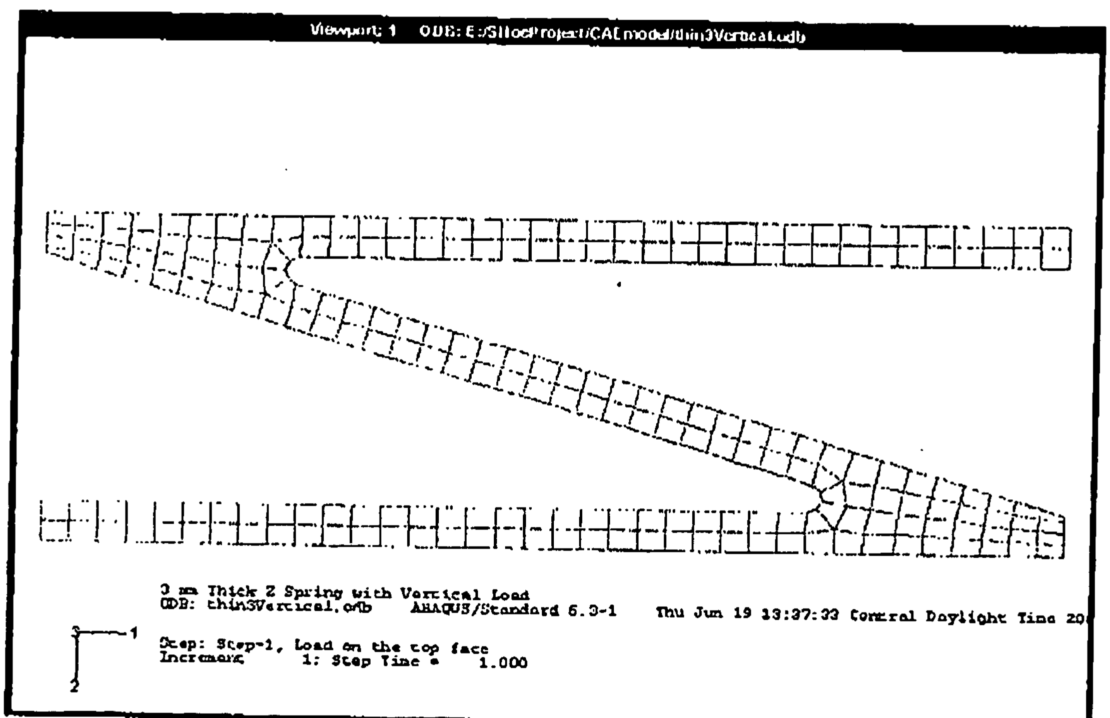

Figure 4. Undeformed Z-Spring with plate thickness of 3mm.

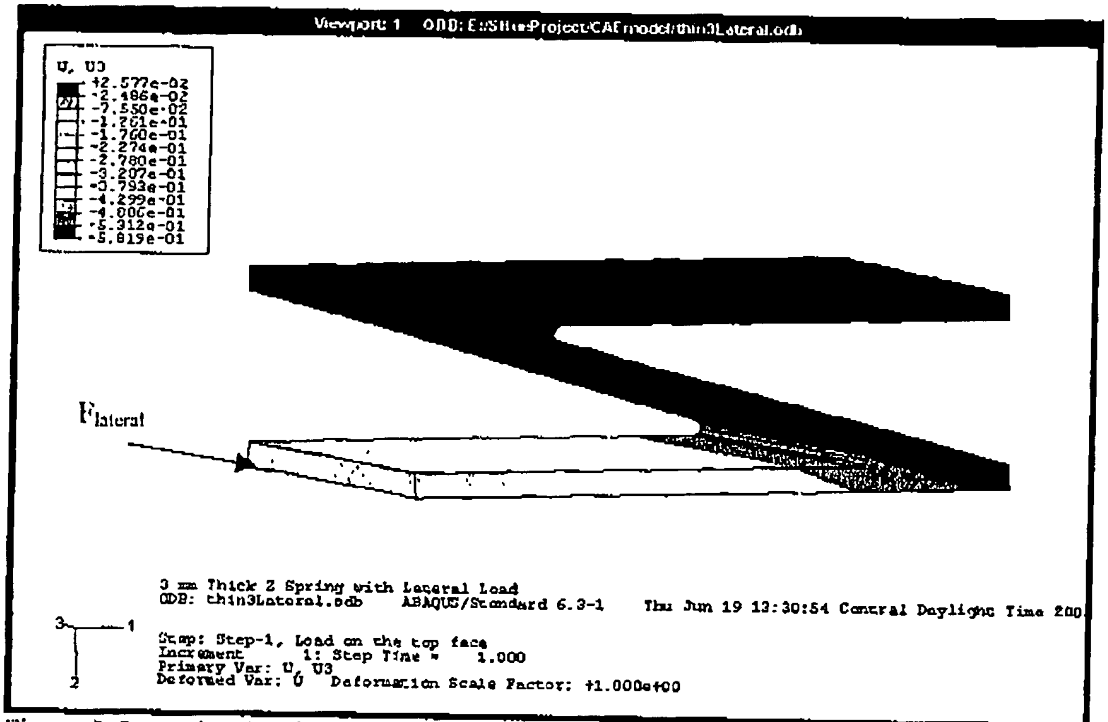

Figure 5. Lateral deflection (mm) of Z-Spring with 3mm thick plates under lateral point load.